International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Intelligent Grid Management for Power and Energy Supply and Distribution

Chandan Kumar Panda [1], Dr. Chittaranjan Panda[2]

Submitted: 23/04/2023 **Revised**: 25/06/2023 **Accepted**: 05/07/2023

Abstract: Modern electrical systems' efficient and reliable distribution of power and energy depend heavily on intelligent grid management. To optimize grid operations, enhanced control and management systems are needed given the increased integration of renewable energy sources and the rising demand for sustainable energy options. In order to effectively monitor, regulate, and optimize power and energy systems, this article suggests an intelligent grid management strategy that integrates smart grid technology, cutting-edge analytics, and control algorithms. The suggested intelligent grid management system makes use of real-time data collection from smart metres, sensors, and other grid equipment to facilitate situational awareness and decision-making. In order to analyze the gathered data and extract insights for grid operation and planning, advanced analytics techniques, including as machine learning and optimization algorithms, are utilized. Utilizingthis information will improve power production, load scheduling, energy storage use, and system stability. In order to encourage energy users to modify their energy consumption habits in response to price signals and grid circumstances, the intelligent grid management system also integrates demand response methods. Demand-side management promotes grid stability and resilience by balancing supply and demand, lowering peak loads. In addition, the suggested approach incorporates distributed energy resources (DERs) into the grid management procedure, including solar panels, wind turbines, and energy storage devices. To maximize their impact on grid performance overall and improve grid resiliency during emergencies, these DERs are coordinated and controlled in a decentralized way. Case studies and simulation results provide as proof of the efficacy of the intelligent grid management strategy. The grid efficiency, energy costs, grid reliability, and integration of renewable energy sources are all improved by the system.

Keywords: *Intelligent grid management, Power and energy supply, Power and energy distribution, Smart grid technologies.*

1. Introduction

Energy is the cornerstone of a sustainable planet, social equality, and economic progress. A significant deficiency in the economy's supply of energy resources is what is known as an energy crisis. Since many recessions are brought on by an energy crisis of some kind, the crisis frequently has an impact on the rest of the economy. Particularly, if the cost of producing energy increases, the cost of producing any good also increases, which has an impact on the development of the country. For humanity to continue existing, access to electricity is both morally required and economically vital. However, approximately a billion people still don't have access to energy worldwide. In addition to the lack of resources, the crisis is also a result of population expansion. The United Nations General Assembly has declared 2012 to be the "International Year of Sustainable Energy for all" in recognition of the significance of energy for sustainable development. Worldwide demand for power is rising in direct proportion to this expansion. By 2040, experts anticipate a surge in global electricity production of 80% (image courtesy of World Economic Forum). The need for electricity is also being fueled by the revolution in information technology and other engineering fields in industrialised nations. Fossil fuels alone cannot satisfy this requirement since they are rapidly running out. The world's climate goals, in particular the aim of keeping global warming to a maximum of two degrees Celsius, are at risk as a terrible side effect of the production of energy using fossil fuels. This conundrum can be resolved by using renewable energy sources to provide power in a manner that is as climate neutral as possible. The G7's commitment to phase out fossil fuels by 2100 gave the development of a carbon-free global energy system a boost in 2015. However, this fundamental change presents us with enormous technical difficulties that call for a whole new approach to controlling our energy system. The three worldwide trends of decentralization, digitization, and decarbonization are altering how we generate, distribute, and use power today. The use of renewable energy is increasing over the world in an effort to follow these trends. The energy system is being expanded with millions of new tiny generating units like wind turbines, solar panels, and biogas facilities. For best effectiveness, they need to be effectively organised and managed. It is technically feasible to obtain approximately 100% renewable energy sources over the next forty years, according to a 2011 research by the World Wild Life Federation (WWF). This means that even after accounting

1 Biju Patnaik University of Technology, Odisha
Email: chandankumarpanda@gmail.com
ORCID ID : 0009-0002-4442-0704
2 Sudhananda Engineering and Research Center, Bhubaneswar
panda_chitaranjan@rediffmail.com
** Corresponding Author Email: chandankumarpanda@gmail.com*

for variations in supply and demand, the energy produced by the sun, wind, water, sea, and earth's heat has the potential to more than meet the world's electrical needs.

1.1. Intelligent controllers for power system applications

In all power system applications, the control mechanism controllers are frequently implemented utilising analogue control with PI controller. Since the parameters of the power system are constantly changing, this calls for extremely detailed mathematical modelling of the system. Because of this, maintaining the stability and reliability of the system requires more effort than using typical PI controllers. The previous efforts concentrated on creating intelligent control techniques to regulate electrical characteristics in the power system to improve its dynamic behaviour. In all engineering disciplines, artificial intelligence (AI), in the form of computer algorithms, has aided in producing the desired results (Tanya et al. 2018). The automatic analysis of operating data, environmental factors, and component characteristics is superior to human analysis. Artificial intelligence approaches have significantly influenced engineering applications, especially in power systems where the control parameters are constantly changing. Heuristic controls based on artificial intelligence provide high levels of resilience and adaptability, which are necessary for the power system to operate reliably. One of the AI methods that incorporates the fundamentals of human thought is the fuzzy logic controller (FLC). According to S. Mishra et al. (2009), the notions of linguistic variables are defined in this controller as a fuzzy set. Membership functions (MF) are used to describe fuzzy sets. The process of turning traditional, or crisp, data collected by sensors and measuring devices into a fuzzy set is known as fuzzy set conversion. The membership function and control rules are combined to create the fuzzy interface, which is what produces the fuzzy output. The process of turning fuzzy data into clear data is called defuzzification. According to applications involving the power system, the fuzzy controller is found to provide higher damping performance under altered system operation conditions (Mansour, D. O. et al. 2009). Because it employs function approximation rather than a typical mathematical model, the Artificial Neural Network (ANN), also known as Neural Networks (NNs), is another AI technology that is frequently employed. Among many other application areas, these include pattern recognition, function approximation optimisation, simulation, and automation. Three fundamental characteristics of ANN may be to blame for the growing interest in them: first, there are no prerequisites or presumptions; second, forecasts are produced by extrapolating from historical data; and third, complicated nonlinear problems are solved sequentially (Rasit Ata 2015). as properly taught, it performs well, and as compared to conventional controllers, tweaking requires less work.

2. Literature Review

A brand-new procedure for lessening glint and improving power quality for a frail grid associated with a breeze ranch utilizing DFIGs was introduced by Hossein Mahvash et al. (2015). The Rotor Side Converter (RSC) of the DFIG utilizes the proposed strategy to direct the result receptive power. The stator voltage control circle with the hang coefficient is introduced to change the grid voltage level in each functional circumstance to deliver the reference responsive power. By utilizing the Stator Voltage Direction Control (SVOC) strategy, the dynamic power is autonomously controlled in the d-hub. The post cancelation technique is utilized to make PI regulators with foreordained bandwidth. While dissecting the gleam discharge at different mean breeze paces, choppiness and changes to the grid qualities are considered.

The STATCOM is analysed by Dinesh Shetty et al. (2017) utilising a model-free methodology and a fuzzy logic controller for reactive current regulation. A thorough STATCOM model is part of the test system. The novel controller has outstanding dynamic responsiveness for step changes in the reactive current reference, it is observed.

A brand-new UPFC with a dual proportional Integral (PI) controller is suggested by Narayan Nahak et al. (2018). To ensure improved performance, the gains are tweaked utilising the Improved Grey Wolf Optimizer (IGWO), Particle Swarm Optimisation Technique (PSO), and DE technique. The dual PI controller controls the phase angle of the shunt converter and the UPFC modulation index of the series converter in order to reduce oscillations in the power system. The findings demonstrate that IGWO approach outperforms PSO & DE technique and that dual PI controller performance is superior to single PI controller.

A fuzzy logic-based MPPT controller can improve the overall performance of the microgrid under partial shade situations, even while the reconfigured PI-based control provides sufficient output parameters (Alajmi et al. 2013). Another body of literature (El Khateb et al. 2014) models a fuzzy logic-based SEPIC converter for MPPT. There is a mismatch between voltage and frequency when non-linear loads predominate in a power network, especially if solar PV penetration is high. In order to achieve voltage regulation, a DSTATCOM is therefore included. The effectiveness of the system increases when FACTS devices are utilised (Indumathi et al. 2012). When charging and discharging are governed by fuzzy rules and power shortfall is addressed, fuzzy based battery management systems also demonstrate their effectiveness (Venkateshkumar, 2016). Due to its flexibility and reliability, hierarchical control in microgrids is gaining importance recently. Battery storage is employed as a backup power source in the literature cited. According to Wandhare et al. (2014), the interfacing of PV resources is investigated under a variety of circumstances, including changes in irradiation level, MPPT, centralised control of actual and reactive powers, and coordinated control. However, sophisticated methods are not used. The intelligent hybrid microgrid is modelled in this paper using the IEEE 1547 standard. This standard is essentially developed to satisfy the technological specifications that can be used globally. Instead of concentrating on the many DR technology types, it focuses on the technical requirements and testing of the interconnection itself. Although this standard recognises that the technical characteristics of DR and the many types of EPSs do have an impact on the connectivity requirements, it nonetheless tries to be technology-neutral. The system and its response will change in some way when DR is added to an EPS (Basso and Friedman 2003). Researchers are concentrating on alternate methods for power generation with decreased environmental pollution and carbon footprint because fossil fuel-based power generation currently does not satisfy consumer power demand due to its availability and pollution. The suggested self-sustaining intelligent microgrid would undoubtedly pave the way for using the technical breakthroughs in the field of renewable production and improving the grid.

3. Methodology

In a microgrid, there are two layers of hierarchical control: local control and central control. Utilizing multiple control algorithms unique to each converter, the local control layer oversees the operation of dispersed power generation sources like photovoltaic (PV) and wind turbine (WT). The local control layer's goals include maximizing power extraction from dispersed generating sources, restricting WT speed, controlling bidirectional converters, regulating AC voltage and frequency, and extending battery life.

The central control layer improves microgrid stability and optimizes energy flow through the use of an EMS with fuzzy logic. In addition to batteries and a dump load, it distributes power among various sources. This power distribution procedure is supervised by the central controller.

3.1. Local Control

The graphic shows how to maximise electricity from a photovoltaic (PV) system by using MPPT (Maximum electricity Point Tracking) control. Due to its low cost and reliable performance, the P&O (Perturb-and-Observe) approach is frequently employed for MPPT control. To maximise power delivery to the DC bus and optimise PV system performance, a boost converter is used. Similar to this, the MPPT technology is applied to wind turbine (WT) generators to maximise power delivery to the DC bus by adjusting the rotor speed. The pair (Cpopt, opt) determines the WT's ideal point, and the speed regulation is changed to produce the ideal amount of power. A cascade control mechanism that controls battery current and DC bus energy maintains the microgrid's power flow balance through controlled currents on the DC bus. It is assumed that the bidirectional converter, which joins the microgrid's parts to the DC bus, is voltage-controlled. Based on a set of criteria, the central controller, such as an Energy Management System (EMS), chooses the suitable energy source (DG or batteries).

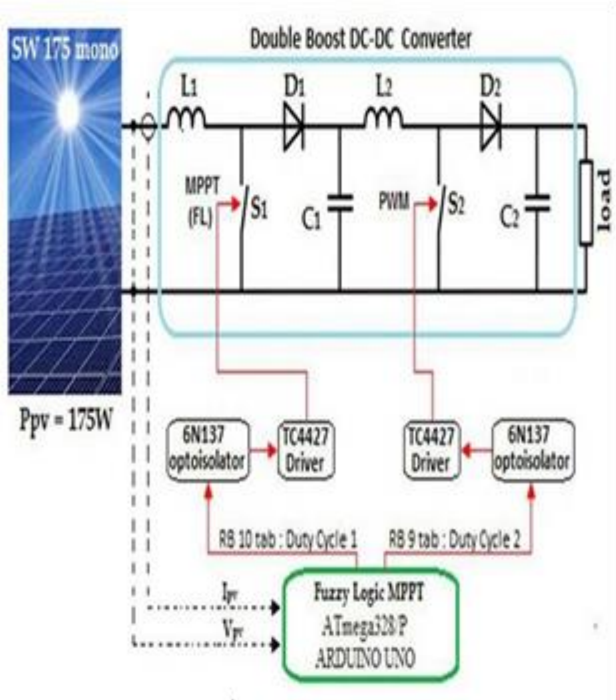

Fig 1: PV generator-boost converter schematic

Overall, the MPPT control methods for PV and WT systems as well as the coordinated regulation of power flow help to maximise the performance and power production of the microgrid components.

3.2. Central Control

FLC is superior to standard mathematical methods because it can handle language knowledge. FLC development relies on the designer's skill rather than the system's mathematical modelling, which requires researchers to solve difficult equations. "Fuzzy sets," Pr. Lotfi Zadeh's 1965 article, founded fuzzy logic. An intelligent EMS based on Mamdani's Fuzzy Inference System (FIS) builds the central controller.

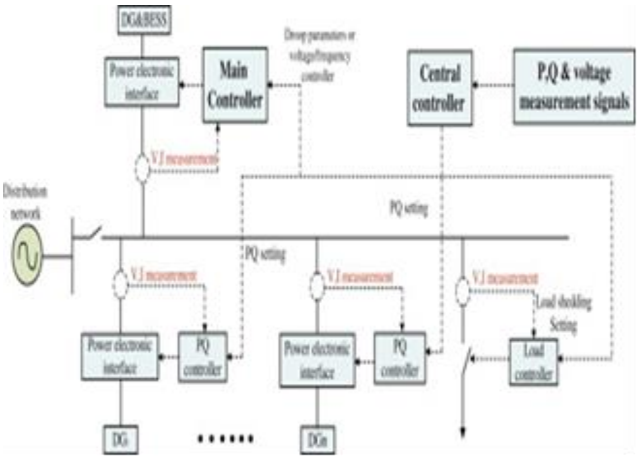

Fig 2: Goals and standards for the central controller.

The EMS controls the power stream among generators and burdens, protects the batteries against profound charge/release, and keeps up with the DC transport voltage to guarantee the exhibition of the MG. The proposed FLC, displayed in Figure 2, is established on the accompanying standards and objectives: The utilization of DGs for load supply is liked. By keeping the SoC somewhere in the range of 20% and 80% and abstaining from cheating or over depleting, battery duration can be delayed. Both the recurrence and the voltage should stay inside a resilience of 0.05 Hz and 10 V, separately.

3.3. Management Algorithm

The microgrid's focal regulator directs a few functional modes and controls power stream all through the framework. The management calculation should be visible in Figure 3. At the point when the batteries are completely energized and the power delivered by the dispersed generators (DGs) surpasses the demand, the reference power for the batteries is changed in accordance with nothing and a dump load is gone on to gobble up the additional power. If the DGs provide insufficient energy and the batteries are empty, the piles are immediately disengaged and the battery reference power is adjusted to zero.

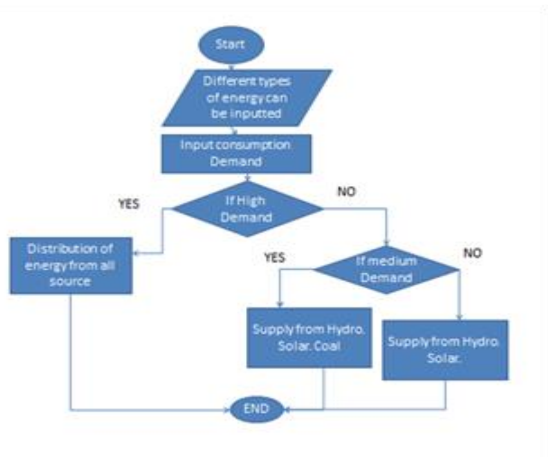

Fig 3: Flow chart of the study

When regulating the system based on the batteries' state of charge (SoC) and the stability of the microgrid, the fuzzy logic controller is essential. The FLC follows a set of regulations. Using membership functions, inputs like SoC, net power, load power, and power source are fuzzified into linguistic variables. Then, based on a set of rules, fuzzy operators are applied to these variables to decide the proper course of action. The outputs of all the rules are combined during the aggregation phase, and defuzzification is then carried out to produce precise control signals. The FLC generates three control signals from load, source, net, and battery SoC inputs: K_{bat}, K_{dump}, and K_{load}. The system's behavior is determined by these control signals.

Figure 4. Defuzzification variables for SoC (a), net power (b), load and source power (c), and switches (d).

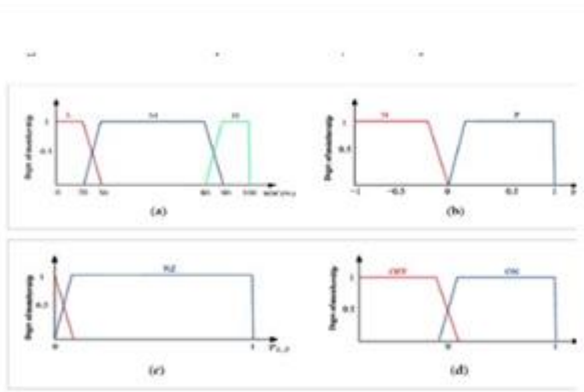

Fig 4 shows defuzzification findings.

FLCs create control signals from inputs and regulations. The microgrid's relays are controlled by these control signals. There are various modes that can be used, including turning off all relays, dumping energy through a load, feeding loads while dumping the extra, charging batteries just partially, or using batteries to supplement DGs in order to satisfy load demand.

3.4. Methods to meet the peak demands

There are a few strategies that can be employed to meet peak demands in a microgrid:

- Distributed Generation (DG) Optimization: The central controller, equipped with an Energy Management System (EMS) and fuzzy logic control, optimize the power flow from distributed generation sources such as photovoltaic (PV) systems and wind turbines (WT). By intelligently allocating power from these sources, the microgrid can ensure that sufficient energy is available to meet peak demand periods.
- Battery Energy Storage: The microgrid incorporates battery energy storage systems to store excess energy during periods of low demand or high generation. These stored energy reserves can then be utilized during peak demand periods to supplement the power generated by

DG sources, thereby meeting the increased load requirements.

- Load Management: The central control layer implements the load management strategies to prioritize and optimize the allocation of power to different loads within the microgrid. By identifying and categorizing loads based on their priority and criticality, the central controller can ensure that essential loads receive power during peak demand periods while temporarily reducing or shedding non-essential loads.
- Demand Response: The microgrid can participate in demand response programs, where consumers are incentivized to reduce their electricity consumption during peak demand periods. The central control layer can coordinate and implement demand response strategies by communicating with end-users and adjusting their power consumption patterns to align with the available power generation capacity.

3.5. Data Collection

To collect data in a microgrid, various methods and techniques can be employed depending on the specific parameters and variables of interest. There are some common approaches for data collection in a microgrid:

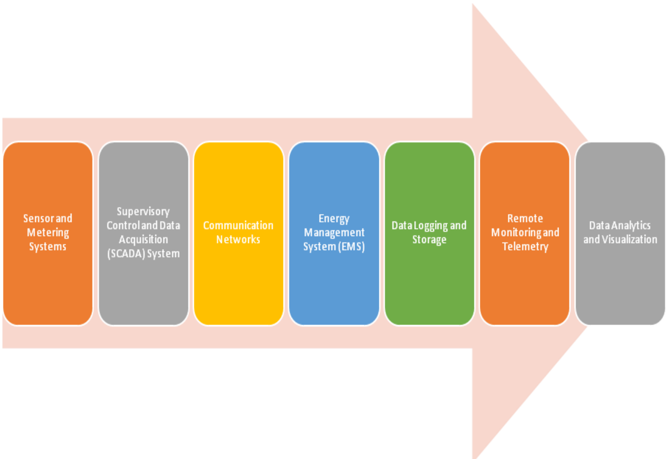

Fig 5: Procedure of Data Collection

- Sensor and Metering Systems: Install sensors and meters at relevant points within the microgrid to measure and monitor key parameters such as voltage, current, power output, battery state of charge, and environmental conditions. These sensors and meters can be connected to a data acquisition system that records and stores the data for analysis.
- Supervisory Control and Data Acquisition (SCADA) System: Use a SCADA system to monitor microgrid data. RTUs and PLCs collect sensor and metre data for SCADA systems. Data is sent to a central control station for analysis and control.
- Communication Networks: Establish a communication network, either wired or wireless, to transmit data from sensors and meters to the central control system. This can involve technologies like Ethernet, Modbus, Wi-Fi, or Zigbee, depending on the specific requirements and constraints of the microgrid.
- Energy Management System (EMS): Utilize an EMS, which serves as the central control layer of the microgrid, to collect and manage data. The EMS can integrate data from various sources, including sensors, meters, and SCADA systems, to monitor and control the microgrid's operation. It can also store historical data for analysis and optimization purposes.
- Data Logging and Storage: Implement data logging systems to record and store the collected data over time. This can involve using databases or dedicated data logging devices. Historical data is valuable for trend analysis, performance evaluation, and decision-making.
- Remote Monitoring and Telemetry: Employ remote monitoring and telemetry systems to collect data from dispersed generation sources and remote components of the microgrid. This allows for continuous monitoring and control even in remote or inaccessible locations.
- Data Analytics and Visualization: Utilize data analytics tools and visualization techniques to process and interpret the collected data. This can involve using algorithms, statistical analysis, machine learning models, and data visualization software to gain insights, detect anomalies, and optimize the microgrid's performance.

4. Results

The inquiry uses a MG Hardware-in-the-Loop platform based on RT-LAB real-time simulation. The HIL platform includes an OP1400 simulator, FPGA controller, and monitoring workstation. The OP4510 simulator receives precise mathematical models of the isolated MG from C-code. The suggested control method operates on the Xilinx FPGA Kintex-7 325T, which generates PWM at 300 kHz with a 4 ns resolution. The OP1400 real-time digital simulator tests power electronics and control systems. The electrical model of the simulated microgrid, local and central controllers, and control plan are included. The Master Subsystem (SM) and Console Subsystem (SC) of the Sim Power Systems model recreate the MG in real time utilising the OPAL-RT platform. The SC contains data exchange blocks for the simulator, whereas the SM contains microgrid component electrical models.

4.1. Description

The usefulness of the suggested hierarchical control strategy will be shown through the use of three experimental examples. The first instance involves evaluating local controllers under challenging load profiles and a range of meteorological variables, including wind, irradiation, and temperature. In the second scenario, the core fuzzy logic controller that manages power distribution across sources, batteries, and dump loads is assessed. Last but not least, the microgrid control is assessed under failure scenarios that include various defects including short circuits and excessive voltages. In order to assess the results' conformance, IEEE 1547 and IEC 61727 are also compared to international standards.

Table 1: FPGA and converter operating frequencies

	Frequency
Xilinx FPGA kintex TM-7 325T	Up to 300kHz, resolution 4 ns
PV converters	25 kHz
Battery converter	10 kHz

Throughout the test, the temperature is kept at 8 °C while the wind blows at a speed of 7 m/s. The datasets for this investigation were taken from a 2018 original publication. The NASA Surface Meteorology and Solar Energy programmes were used to acquire meteorological information, including solar radiation, wind speed, and ambient temperature for the microgrid under study, which is situated in a remote region of Morocco.

The 20 kHz PV converter and 10 kHz battery converter can be controlled using the Xilinx FPGA KintexTM-7 325T's superior PWM generation. It operates at 200 kHz with 5 ns resolution. The OP1400 real-time digital simulator can test and model control, power electronics, and other embedded real-time systems. The simulator now includes the replicating microgrid's electrical model, local, and central controllers. Controllers manage system operations and implement the electrical model's representation of component electrical activity.

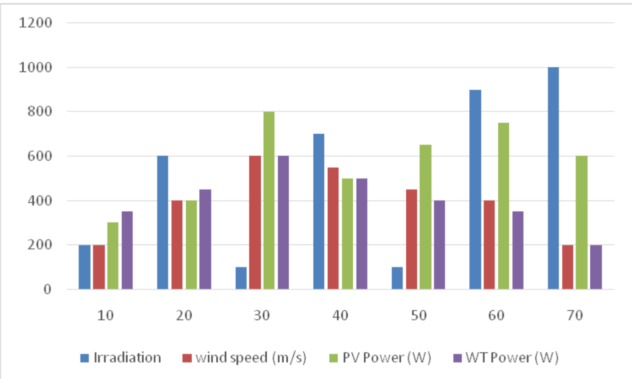

Fig 6: View of Climate condition

4.2. Local Controllers Test-1

Figure 7 illustrates solar and wind turbine electricity. The Microgrid (MG) responded correctly to extreme weather and variable load demand. With a +/1 V overrun, the DC bus voltage matches the reference voltage and stays at 500 V.

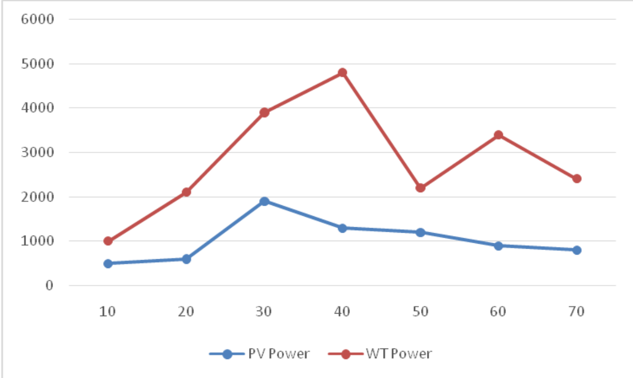

Fig 7: PV panels and WT generator electricity

4.3. Central Controller Test -2

Regardless of wind speed and irradiance, air conditioner voltage remains constant. DC transport, which is directly related to the inverter, directly affects heap voltage and frequency. The recommended EMS can provide a stable voltage and current to the heap that meets waveform and symphonious contortion specifications. The SoC's safe range is 20%–80%. This also illustrates that the microgrid can handle sustainable energy and feed the heap with continuous and high power despite climate variations and fluctuating burden demand. As shown in Figure 7, the heap power and its reference are the same, indicating that the microgrid can maintain a predictable power progression even when the DGs are not producing enough energy. As seen in Figure 7, energy storage devices like batteries can power the heap during power outages. When charged, batteries have positive power; when released, they have negative power. This means that the MG can efficiently direct power between the DGs and the heap by storing extra energy in the batteries and distributing it during shortages.

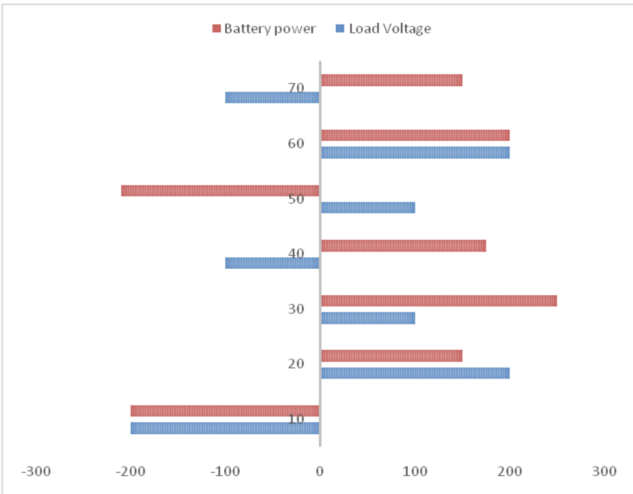

Fig 8: power consumption and batteries power

4.4. Performance of Microgrids under Defective Conditions-Test 3

The efficiency of the suggested hierarchical control method in managing short circuits is assessed in the final test. A three-phase short circuit occurs at the Point of Common Coupling (PCC) in the interval 10-10.1 s, and the DG-side breakdown occurs in the interval 15-15.1 s. This test's objective is to look at how the central controller acts and reacts to these failures. Even though faults were simulated, after the fault was fixed the system was still able to stabilise. The DC bus voltage lowers dramatically and fluctuates noticeably while the short circuit takes place. However, after the problem is fixed at 12.2 seconds, it returns to normal, demonstrating the robustness and effectiveness of the suggested hierarchical control strategy for handling short circuits. When the fault happens, the frequency fluctuates just 0.2%, which is very little. Once the issue has been resolved, the frequency stays at 50 Hz as it was originally. THD fluctuation over time, which is still very low in the defective regime, can reach 2.5 during 100 ms. To assess the efficiency of the strategy in the fault regime, results must adhere to international standards. Recommendations for voltage overshoots and response time are outlined in IEEE 1547 and IEC 61727. System safety is decreased when the PCC is overvoltaged over an extended period of time. According to IEC 61727, an isolated microgrid's overvoltage can occur in one of four ranges:

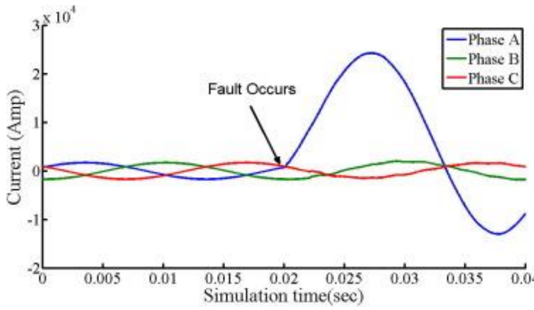

Fig 9: DC bus voltage before and after a problem

The greatest allowed travel time is 0.1 seconds when the voltage is half. The greatest reasonable outing term is 2 s when half Voltage > 85%. At the point when voltage is somewhere in the range of every available ounce of effort and 120%, the longest outing time allowed is 2 s. The longest travel time allowed at 120% voltage is 0.16 seconds. Furthermore, the MG ought to have the option to support a THD of under 5% over a recurrence scope of 1 Hz at the PCC.

Table 2summarises the microgrid's load power and frequency. All five parameters meet IEEE 1547 and IEC 61727 standards.

Table 2: performance of the micro grid

	Healthy Regime	Faulty Regime
Time of responses	0.05s	0.3s
Changes in Frequency	±0.004 Hz	±0.079 Hz
Changes in voltage	±0.8%	±30%
Clearing time	0.04 s	0.152 s
THD	0.42%	6%

5. Conclusion

An MG Hardware-in-the-Loop (HIL) platform built on the RT-LAB system is used for the study. It consists of an FPGA controller, OP1400 simulator, and monitoring workstation. The C-code version of the MG's mathematical model is posted to the OP4510 simulator. The control algorithm is executed at a high frequency of up to 300 kHz with a resolution of 4 ns using the Xilinx FPGA Kintex-7 325T. With the MG's electrical model and local/central controllers, the OP1400 simulator functions as a real-time digital simulator. Three test cases—local controller performance, central controller assessment, and microgrid behaviour under fault conditions—are examined in the paper. For precise load consumption estimation, meteorological data from NASA programmes is employed. Test 1 demonstrates the microgrid's precise responsiveness to load variations and weather changes. Test 2 shows how well the Energy Management System (EMS) works to manage battery charge and provide a steady power supply. Test 3 certifies the fault handling and voltage and frequency stability of the hierarchical control method. The study's outcomes meet the requirements of IEEE 1547 and IEC 61727, demonstrating the viability of the control strategy. Overall, the study emphasises how reliable local and central controllers are and how the microgrid can continue to provide stable power in difficult circumstances.

References

[1] Tanya, S., Deepak, K. B., & Chakrabarti, S. (2018). Artificial Intelligence and Its Application in Different Areas. In 2018 3rd International Conference on Communication and Electronics Systems (ICCES) (pp. 189-192). IEEE.

[2] Mishra, S., Bhende, C. N., &Mithulananthan, N. (2009). Fuzzy logic-based automatic generation control of a multi-area power system. Electric Power Systems Research, 79(2), 298-308.

[3] Mansour, D. O., Alomoush, M. I., & Hariri, A. A. (2009). Fuzzy logic controller for damping inter-area oscillations in multi-machine power systems. Energy Conversion and Management, 50(1), 41-47.

[4] Ata, R. (2015). Artificial neural networks: fundamentals, computing, design, and application. Journal of Advanced Computational Intelligence and Intelligent Informatics, 19(1), 1-4.
[5] Mahvash, H., Seifi, A. R., &Noroozian, R. (2015). Mitigation of flicker and power quality improvement in a wind farm connected to a weak grid using DFIGs. In 2015 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC) (pp. 1-6). IEEE.
[6] Shetty, D., Panda, A., Singh, B. N., & Panda, S. (2017). Model-free fuzzy logic controller for STATCOM reactive current control. In 2017 IEEE Power and Energy Society General Meeting (PESGM) (pp. 1-5). IEEE.
[7] Nahak, N., Tripathy, M., Nayak, S., Panda, S., & Nayak, N. (2018). Dual PI controller-based UPFC for power system oscillation damping using improved grey wolf optimizer. International Journal of Electrical Power & Energy Systems, 96, 1-12.
[8] Alajmi, B. N., Ahmed, M. S., & Finney, S. J. (2013). Fuzzy logic-based maximum power point tracking for photovoltaic systems experiencing partial shading conditions. IEEE Transactions on Energy Conversion, 28(4), 893-901.
[9] El Khateb, A., &Ouassaid, M. (2014). Design and implementation of a fuzzy logic-based SEPIC converter for maximum power point tracking. Renewable Energy, 64, 13-21.
[10] Indumathi, R., Gowrishankar, S., & Venkatesh, P. (2012). Design of distribution static compensator (DSTATCOM) for voltage regulation in the presence of non-linear loads. International Journal of Electrical Power & Energy Systems, 43(1), 330-337.
[11] Venkateshkumar, R. (2016). Fuzzy logic-based battery management system for renewable energy systems. In 2016 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES) (pp. 1-5). IEEE.
[12] Wandhare, R. G., Chaudhari, P. R., &Kolhe, J. P. (2014). Coordinated control of distributed energy resources in a hybrid microgrid. In 2014 International Conference on Energy Efficient Technologies for Sustainability (ICEETS) (pp. 530-535). IEEE.
[13] Zadeh, L.A. Fuzzy sets. Inf. Control 1965, 8, 338–353
[14] Zerk, A.E.; Ouassaid, M.; Zidani, Y. Feasibility Study and Optimization of a Standalone Hybrid System for Remote Area: A Case Study of High Atlas Mountains in Morocco. In Proceedings of the 2018 IEEE 5th International Congress on Information Science and Technology (CiSt), Marrakech, Morocco, 21–27 October 2018; pp. 606–611
[15] 1547-2018—IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces|IEEEStandard|IEEE Xplore. Available online: https://ieeexplore.ieee.org/document/8332112 (accessed on 25 January 2022).
[16] IEC 61727:2004|IEC Webstore|Invertor, Smart City, LVDC. Available online: https://webstore.iec.ch/publication/5736 (accessed on 25 January 2022).
[17] Eamani, R. R. ., & Kumar, N. V. . (2023). Design and Analysis of Multiplexer based Approximate Adder for Low Power Applications. International Journal on Recent and Innovation Trends in Computing and Communication, 11(3), 228–233. https://doi.org/10.17762/ijritcc.v11i3.6341
[18] Ms. Ritika Dhabalia, Ms. Kritika Dhabalia. (2012). An Intelligent Auto-Tracking Vehicle. International Journal of New Practices in Management and Engineering, 1(02), 08 - 13. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/5